Granular Computing:

A Paradigm in Information Processing

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Granular computing (GrC): Outline

- Introduction
- Definitions and framework
- Background
- Philosophy
- Advantages
- Structure
- Basic issues
- Computing in GrC domain
- Concluding remarks

Granular Computing (examples)

1. For travelling one needs to know about the weather conditions like sunny, cloudy or rainy etc. instead of exact temperature,

2. While establishing a course view of the world-map, we deal with high-level information like continents, countries, and oceans. When more details are required, we move down to regions, provinces, states, seas, etc.

Granular Computing (examples)

Technical writing:

One can easily observe multiple levels of granularity in any technical writing:

High level of information

- title, abstract

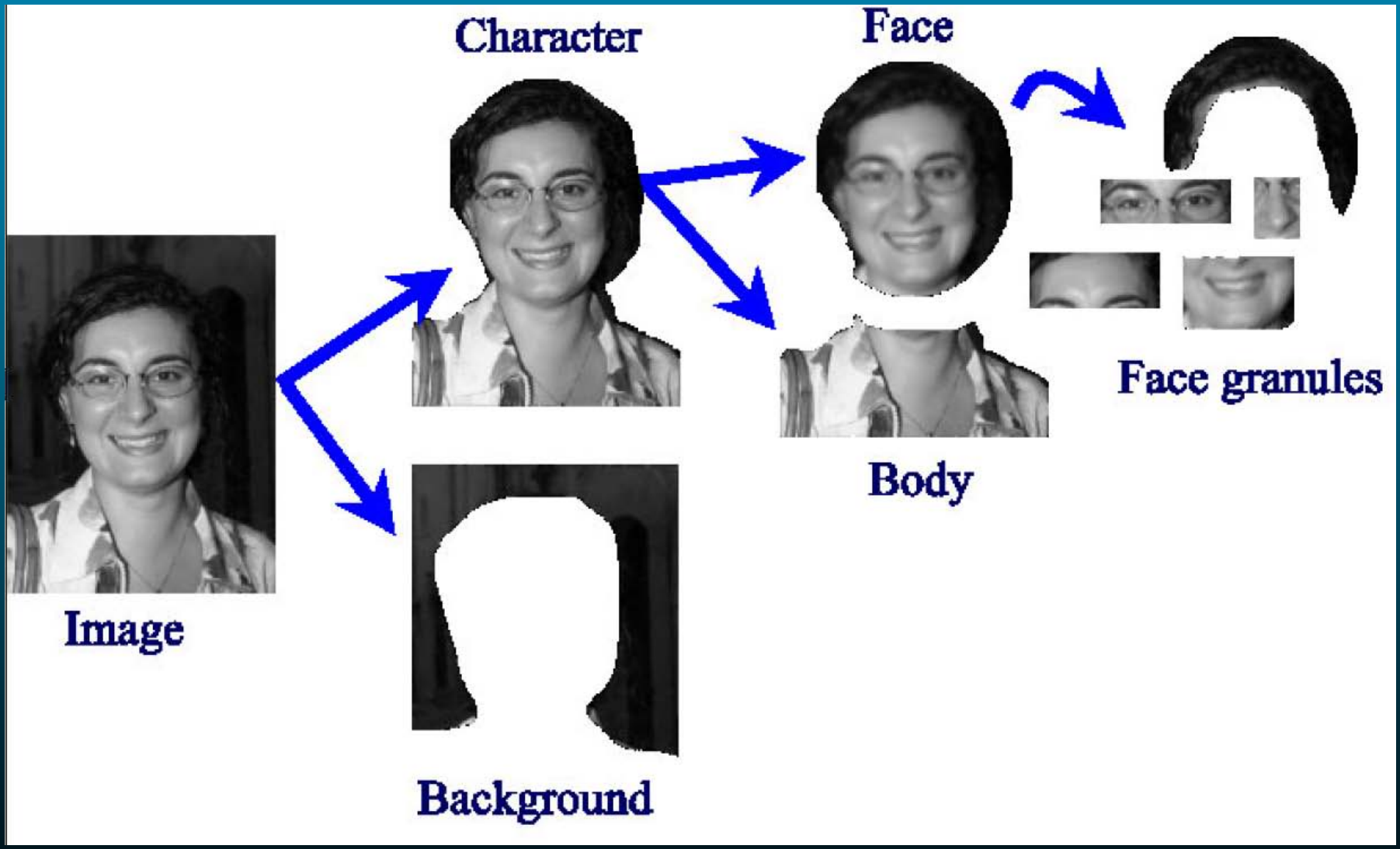
Middle levels of information

- chapter/section titles
- subsection titles
- subsubsection titles

Low level of information

- text

Granular Computing (examples)



Granular Computing (definition)

Granular Computing

- An umbrella term to cover any theories, methodologies, techniques, and tools that make use of granules in problem solving.
- Process of performing computation and operations on granules.

A Framework of GrC

Basic components:

- Granules
- Granulated views
- Hierarchies.

Basic structures:

- Internal structure of a granule
- Collective structure of granulated view (a family of granules)
- Overall structures of a family of granulated views

A Framework of GrC

Historical notes

Main driving force of GrC

- Fuzzy set, and
- Rough set theories

However, the connections to other fields and the generality, flexibility, and potential of GrC have not been fully explored.

FUZZY LOGIC—A BRIEF SUMMARY

Misconceptions about fuzzy logic.

Fuzzy logic is not fuzzy, In essence,

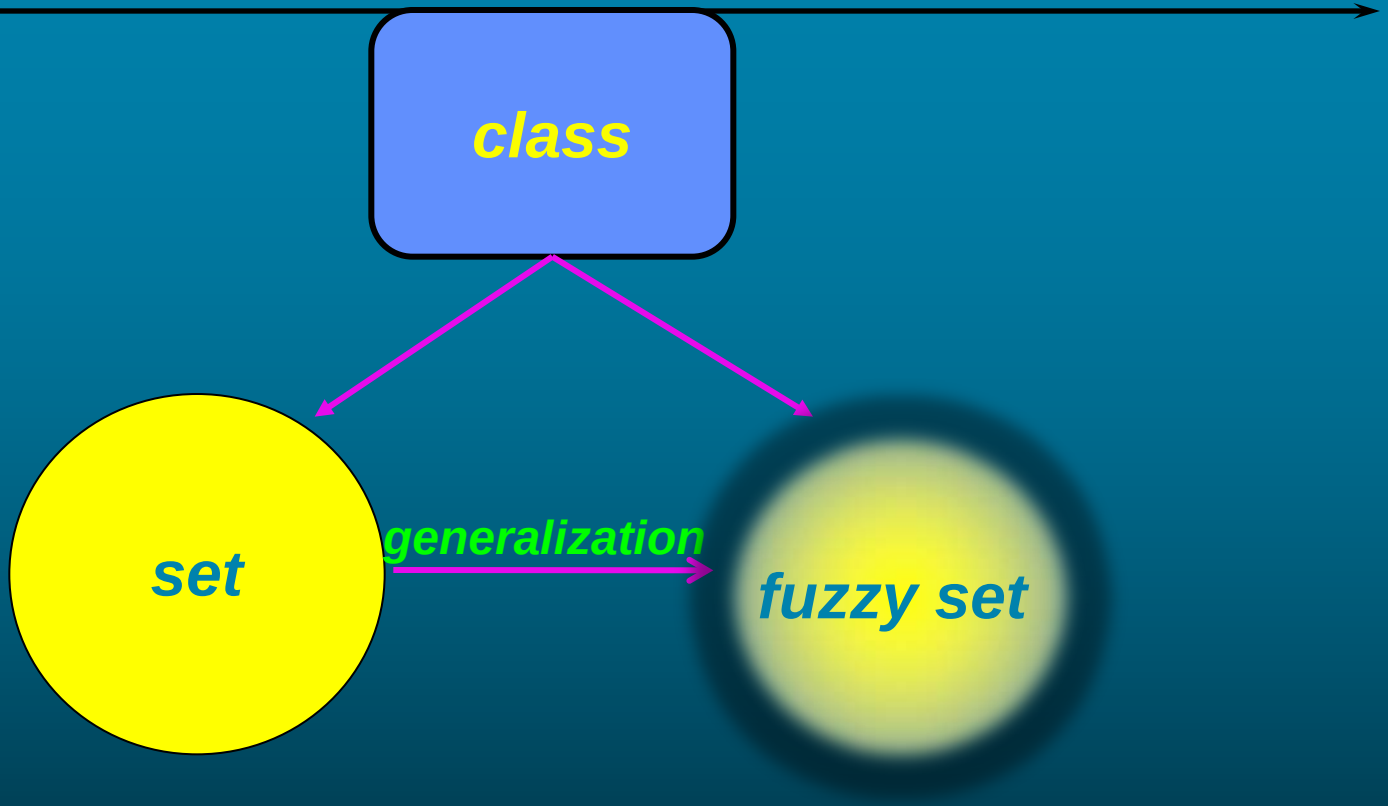
fuzzy logic is a precise logic of imprecision.

The point of departure in fuzzy logic—the nucleus of fuzzy logic, is the concept of a fuzzy set.

EXAMPLE: Age of a person

Young, Old

The concept of Fuzzy set (ZADEH 1965)



Informally, a fuzzy set, A, in a universe of discourse, U, is a class with a fuzzy boundary .

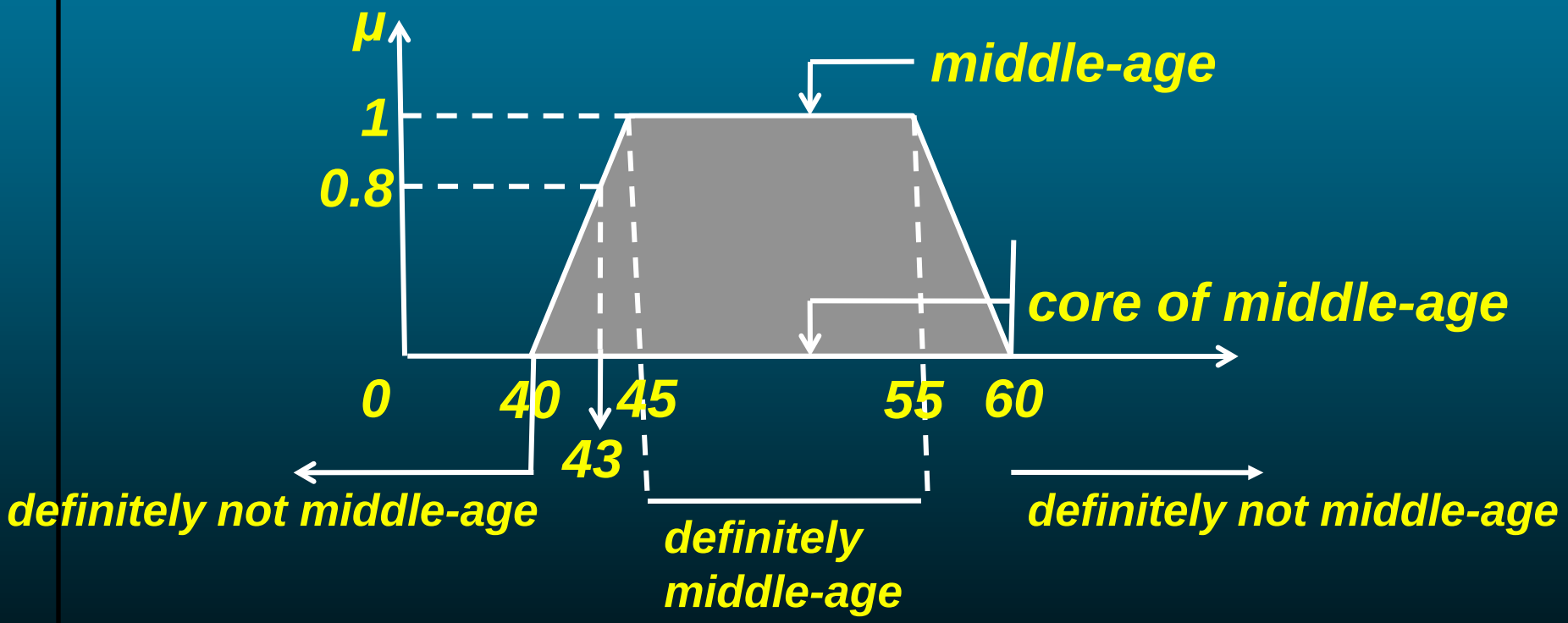
Continued….

- A set, A, in U is a class with a crisp boundary.
- A set is represented through association with a characteristic function c_A: U {0,1}
- A fuzzy set is represented through graduation, that is, through association with a membership function μ_A: U [0,1], with $\mu_A(u)$, $u \varepsilon U$, representing the grade of membership of u in A.
- Membership in U is a matter of degree.
- In fuzzy logic everything is or is allowed to be a matter of degree.

EXAMPLE—MIDDLE-AGE, IMPRECISION OF MEANING

Imprecision of meaning = elasticity of meaning

Elasticity of meaning = fuzziness of meaning

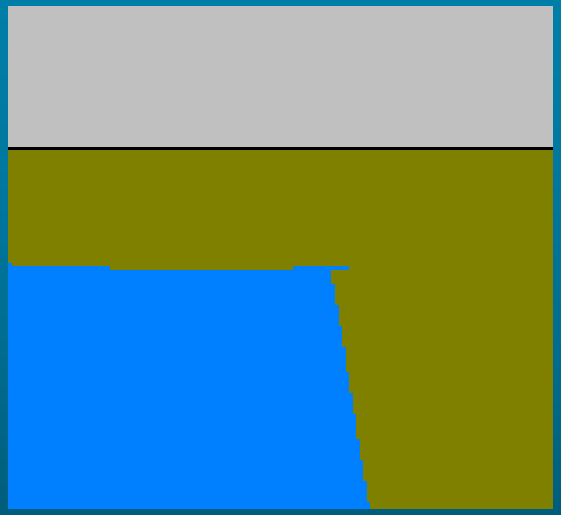


Fuzzy information granulation

Granules

- Crisp

- Fuzzy



Fuzzy Information Granulation (FIG)

FIG deals with

- Imprecise representation of information,
- Problems having insufficient information.

Historical notes

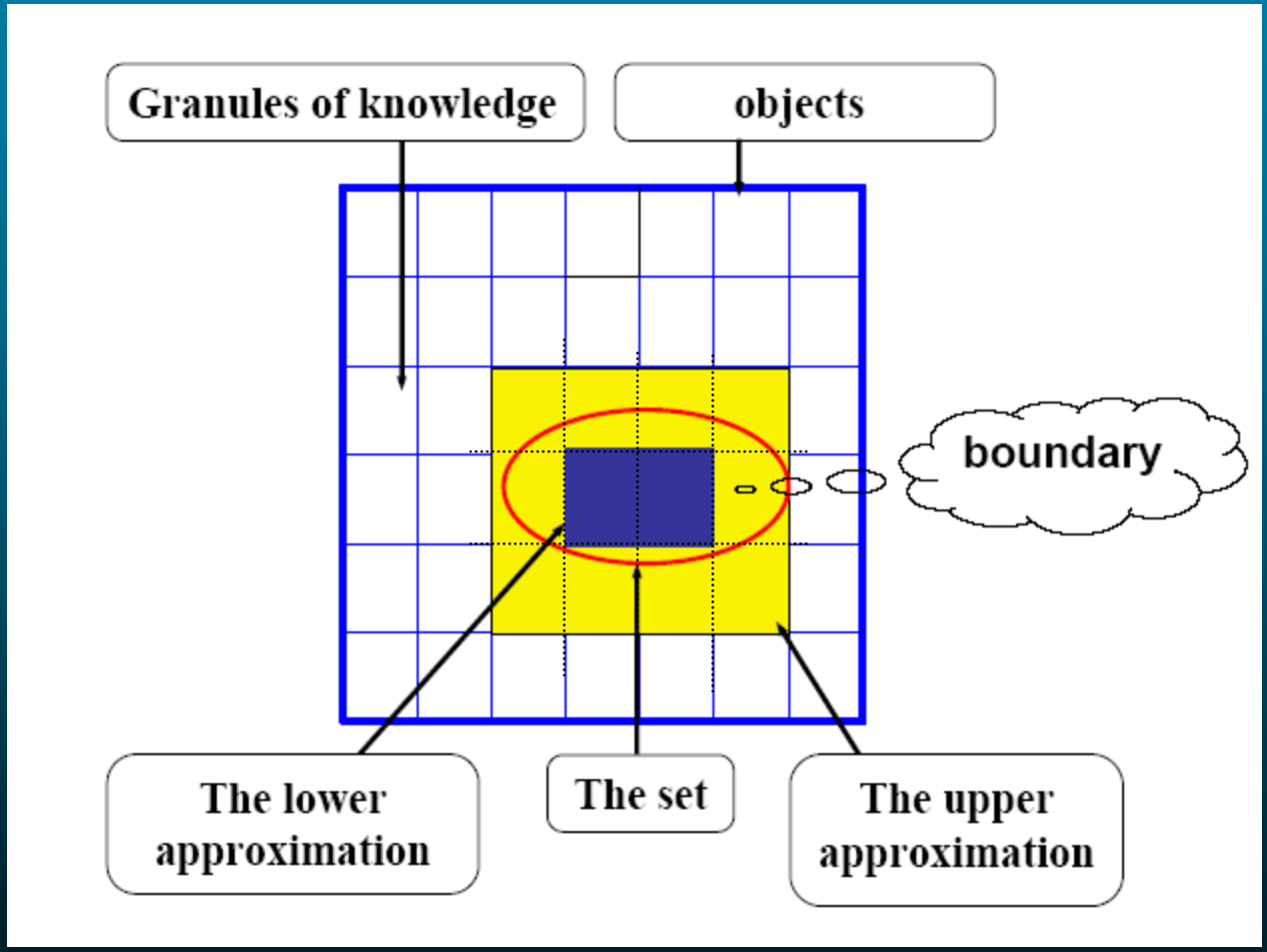
Rough sets perspectives:

1982, Pawlak introduced the notion of rough sets.

1998, the GrC view of rough sets was discussed by many researchers (Lin, Pawlak, Skowron, Y.Y. Yao, and many more).

Rough set theory can be viewed as a concrete example of GrC.

The concept of Rough set (PAWLAK 1982)



Granulation (Rough and/or Fuzzy)

- Fuzzy granulation
- Rough granulation
- Rough-fuzzy granulation
- Fuzzy-Rough granulation

The Concept of GrC is not New…

The basic ideas and principles of GrC have appeared in many fields:

- Artificial intelligence,
- Cluster analysis, Interval computing,
- Quotient space theory,
- Belief functions,
- Machine learning, Data mining,
- Databases, and many more.

Human Problem Solving

GrC = Problem solving based on different levels of granularity (detail / abstraction).

Level of granularity is essential to human problem solving.

GrC

- attempts to capture the basic principles and methodologies used by human in problem solving.
- models human problem solving qualitatively and quantitatively.

Philosophy: Human Knowledge

- Human knowledge is normally organized in a multiple level of hierarchy.
- The lower (basic) level consists of directly perceivable concepts.
- The higher levels consists of more abstract concepts.
- Human perceives and represents real world at different levels of granularity.
- Human understands real world problems, and their solutions, at different levels of abstraction.
- Human can focus on the right level of granularity and change granularity easily

CAN WE COMPUTE THESE ?

Granules (visualization)

Granules are regarded to as the primitive notion of granular computing.

A granule may be interpreted as one of the numerous small particles forming a larger unit.

A granule may be considered as a localized view or a specific aspect of a large unit.

Granules (examples)

- In a set-theoretic model, a granule may be a subset of a universal set (rough sets, fuzzy sets, cluster analysis, etc.).
- In planning, a granule may be a sub-plan.
- In theorem proving, a granule may be a sub-theorem.

Granules (properties)

- Shape
- Size

It may be interpreted as the degree of abstraction, concreteness, or details.

In a set-theoretic setting, the cardinality may be used to define the size of a granule.

Granules (relationship)

Connections and relationships between granules can be modeled by binary relations.

They may be interpreted as dependency, closeness, overlapping, etc.

For example,

Based on the notion of size, one can define order relations, such as “greater than or equal to”, “more abstract than”, coarser than”, etc.

Granules (operations)

Operations can also be defined on granules.

One can combine many granules into one or decompose a granule into many.

The operations must be consistent with the relationships between granules.

However,

One can consider operation (size / shape) as class-dependent, as an example.

Advantages of GrC

- GrC leads to clarity and simplicity.
- GrC leads to multiple level understanding.
- GrC is more tolerant to uncertainty.
- GrC reduce costs by focusing on approximate solutions (solution at a higher level of granularity).

… … …

Granular Structures

Internal structure of a granule:

At a particular level, a granule is normally viewed as a whole.

The internal structure of a granule need to be examined. It provides a proper description, interpretation, and the characterization of a granule.

Such a structure is useful in granularity conversion.

Granular Structures

Overall structure of a hierarchy:

It reflects both the internal structures of granules, and collective structures of granules in a granulated view.

Two arbitrary granulated views may not be comparable.

Basic Issues of GrC

Two major tasks:

- **Granulation, and**
- **Computing and reasoning with granules.**

Basic Issues of GrC

Algorithmic vs. semantic studies:

Algorithmic studies focus on procedures for granulation and related computational methods.

Semantics studies focus on the interpretation and physical meaningfulness of various algorithms.

Granulation (criteria)

- Why two objects are put into the same granule.
- Meaningfulness of the internal structure of a granule.
- Meaningfulness of the collective structures of a family of granules.
- Meaningfulness of a hierarchy.

Criteria leads to granulation methods:

How to put objects together to form a granule?

Construction methods of granules, granulated views, and hierarchies.

Granulation

Representation/description:

Interpretation of the results from a granulation method.

Find a suitable description of granules and granulated views.

Computing With Granules

Granularity conversion:

A basic task of computing with granules is to change granularity when moving between different granulated views.

A move to a detailed view reveals additional relevant information.

A move to a coarse-grained view omits some irrelevant details.

Computing With Granules

Property preservation:

Computing with granules is based on principles of property preservation.

A higher level must preserve the relevant properties of a lower level, but with less precision or accuracy.

Concluding Remarks

GrC is an interesting research area with great potential.

One needs to focus on different levels of study of GrC.

- The conceptual development.
- The formulation of various concrete models (at different levels).

The philosophy and general principles of GrC is of fundamental value to effective and efficient problem solving.

GrC may play an important role in the design and implementation of next generation information processing systems.

Thanks for the Patience